Does the Learning Medium Matter?

A Study on the Use of Low-cost Tablets in the Classroom, and Observations on the Digital Divide

A report by

December 5, 2012

This report is based on a paper titled "Does the Learning Medium Matter? Impact of Low Cost Android Tablets on Elementary Students' English Comprehension, Perceived Performance and Memory Retention" by El-Mouelhy, Poon, Hui, and Chan; submitted to *The International Journal of Human-Computer Interaction*

Sponsors

Contents

Part I: Introduction

Digital Division in the Age of Touch-based Computing

The digital divide is a term that refers to inequalities in access to important information and communication technologies (ICTs) that are increasingly essential to life in modern societies. Those without sufficient regular access to essential technologies bear social and economic disadvantages where ICTs are widespread; similarly, nations with lower rates of ICT penetration bear disadvantages compared with more technologically advanced nations.

While people of all ages are affected by the digital divide, ThinkBlaze believes that children are at greater risk of incurring disadvantages as a result of inadequate access to important technologies. Given the rapid advance of ICT, today's technology-poor children can be expected to struggle while their technology-rich counterparts enjoy head starts in education, job-seeking, social life, general economic opportunities, and other aspects of modern life.

The sponsors of this study have been involved in a number of programs to donate refurbished second-hand PCs to schools in need. But today, at the dawn of the age of touch-based computing, there is a danger of further increases in the digital divide. Disadvantaged children often have limited exposure to personal and touch-based computing – in spite of the fact that touch-based technology is highly accessible and contains a broad range of attractively-priced products.

The ThinkBlaze Initiative

Earlier this year, Animoca and Outblaze donated 49 low-cost 7-inch Android 4.0 tablets (Ainol Novo7 Paladin) to a school in need of mobile touch computing resources. It was an opportunity to explore options for narrowing the digital divide while investigating the impact of tablet technology on schoolchildren. Outblaze set up ThinkBlaze to conduct the research and, in general, to discuss interesting ideas in technology. ThinkBlaze worked with the Department of Applied Social Studies, City University of Hong Kong to document what happened after classes of children regularly used the donated tablets in class for one month.

The devices in question – costing roughly USD 76 (HKD 590) at the time - represented a cost-effective opportunity to equip multiple classes of students at one school with current tablet technology. Although the devices were shared among classes, each student enjoyed regular access to the tablets. Students used the devices regularly for just over a month, after which we ran tests to assess the impact of low-cost tablets on primary school students.

Access to students was restricted in order to avoid unnecessary disruptions to the school's curriculum, particularly so close to the end of the semester. This limited access meant that we were unable to take a standard approach with all children; we were forced to segment our research into grades 4 & 6 (tested for reading comprehension and perceived performance) and grade 1 (tested for memory retention).

Peril and Opportunity

The research literature on the impact of ICT on children's reading comprehension is mixed, containing evidence of both beneficial and detrimental effects. A review of some studies dating from the late 1990s to the present is included in the paper submitted to a peer-reviewed journal; here we'd like to share some findings for the purposes of discussion and feedback.

The students responded enthusiastically to their new tablets, but we were also mindful of the potentially disruptive effect of ICT on young minds, and not only because the first (and natural) impulse of the children was to view the devices as new toys. Would the tablets have an impact on academic performance? Are some children too young to be exposed to some technologies? We set out to investigate some of these questions. We do not pretend to have the answers, but hope that our work contributes to an fascinating and evolving field of inquiry.

Summary of Findings

Please find details and discussion for all the below in the relevant sections of this report.

Reading comprehension: fourth-grade students scored higher when reading on paper than on tablet, whereas grade 6 students scored similarly on both media.

Perceived performance: fourth- and sixth-grade students who completed the reading comprehension tests reported their perceived performance. We found an interaction effect between "medium" and "gender" in the perceived performance of fourth-graders: boys reported higher perceived performance when reading on tablets, while girls reported higher perceived performance when reading on paper. Among the sixth-graders we found no statistically significant differences between paper and tablet use for perceived performance scores.

Memory retention: first-grade students who attempted to memorize a set of images presented on paper and on tablets obtained higher correct memory scores when they viewed the images on paper; however, their lower scores when using tablets could be explained by experimental procedure (see discussion).

Academic performance: the teachers of grades 1, 4 and 6 students participating in this study reported no effect on academic performance after one month of regular in-class tablet use, although we suspect that longer exposure is necessary to determine the impact of tablets on academic performance.

A Note on This Report

This document is intended for convenient public consumption; it is based on work partially described in a research paper titled "Does the Learning Medium Matter? Impact of Low Cost Android Tablets on Elementary Students' English Comprehension, Perceived Performance and Memory Retention" by El-Mouelhy, Poon, Hui, and Chan; submitted to *The International Journal of Human-Computer Interaction*.

Part II: The Results

Reading Comprehension (Grades 4 & 6)

One of the major applications of tablets in education is for the use of e-textbooks, and therefore we tried to detect any difference in English language reading comprehension scores when students read passages from tablets and from printed paper.

Reading Comprehension, Grade 4
In a group of 18 grade 4 students (aged 9-12 years; 11 male and 7 female) both boys and girls showed statistically significantly higher reading comprehension scores when reading a passage on printed paper than when using a tablet. The results are graphed in Figure 1.

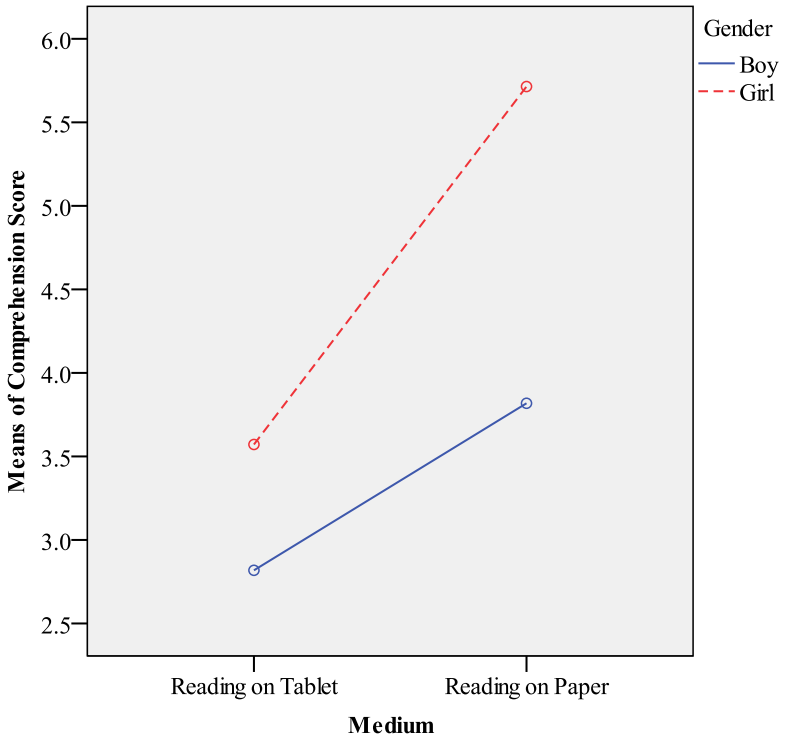

Figure 1. Means plot of Reading Comprehension Performance Score by Medium across Two Gender Groups for Grade 4 Students

Reading Comprehension, Grade 6

In a group of 36 grade 6 subjects (aged 11-16 years; 17 male and 19 female) we detected no statistically significant difference in reading comprehension scores between subjects using tablet and paper media. The results are graphed in Figure 2.

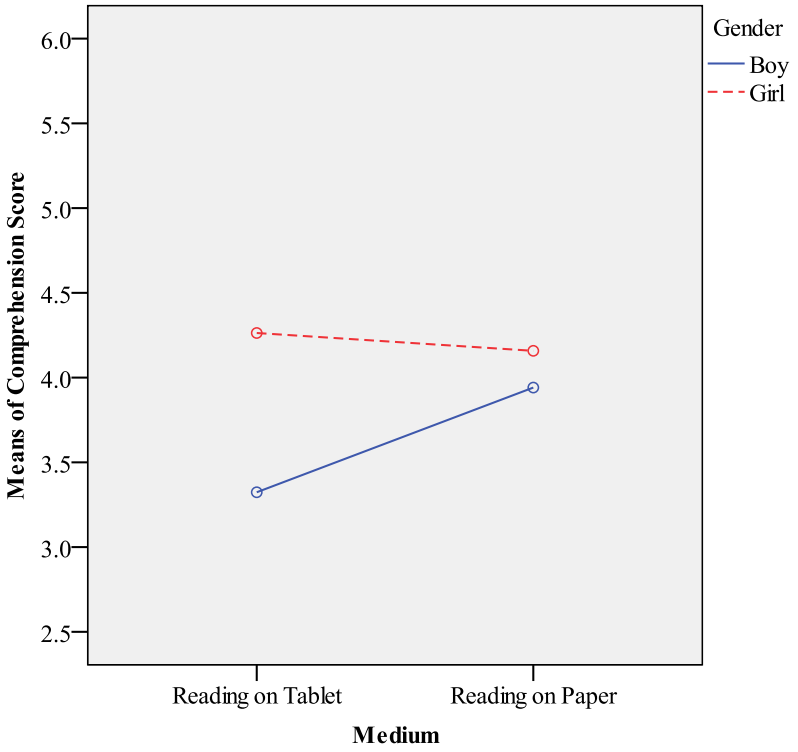

Figure 2. Means plot of Reading Comprehension Performance Score by Medium across Two Gender Groups for Grade 6 Students. Differences arising from medium were not considered statistically significant.

Discussion

The above results suggest that tablets have a negative impact on reading comprehension for fourth-graders, but not for sixth-graders. It should be noted that subjects had been using printed paper as their primary medium for years, whereas the Android tablets were a novel medium to which students may not have had sufficient time to become habituated.

It's also worth noting that some recent studies have found that the use of ICTs decreases children's reading performance (Jeong, 2012; Sheppard, 2011). We detected this negative impact of ICT for grade 4 students but not for grade 6 students, perhaps suggesting that as children age or advance to higher learning levels they become more resistant or adaptive to ICTs' detrimental effects on reading comprehension.

The full study includes more detailed discussion, however our most obvious insight from this project is that both caution and attention are required when dealing with young students because ICTs do have the potentially to be disruptive. This is a field of inquiry that can only benefit from further research.

Perceived Performance (Grades 4 & 6)

After administering the reading comprehension tests we asked the same grade 4 and grade 6 students to evaluate their perceived performance on those tests using a questionnaire with 5 questions in 6-point Likert scale.

Perceived Performance, Grade 4

Grade 4 boys were more confident of their performance when using tablets, while girls thought they performed better when using paper. Interestingly, both boys and girls had very similar perceived performance scores when using tablets, even though girls thought they performed *better* on paper, whereas boys thought they performed *worse* on paper. The results are graphed in Figure 3.

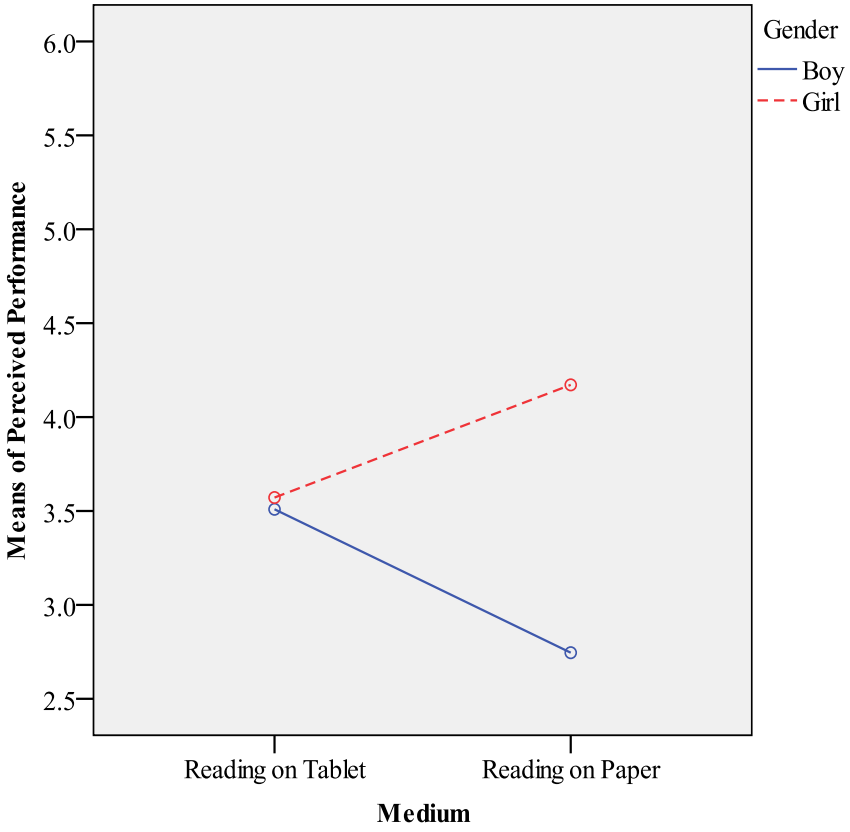

Figure 3. Means plot of Perceived Performance Score by Medium across Two Gender Groups for Grade 4 Students

The situation is also illustrated in Figure 4 (see page 10), which provides an informal cross-comparison of fourth-graders' reading comprehension performance against perceived performance (this is achieved by the simple expedient of converting comprehension scores and perceived performance scores to percentages).

Perceived Performance, Grade 6

Among grade 6 students there was no statistically meaningful difference in perceived performance between the use of tablets or paper. The results are shown in Figure 5.

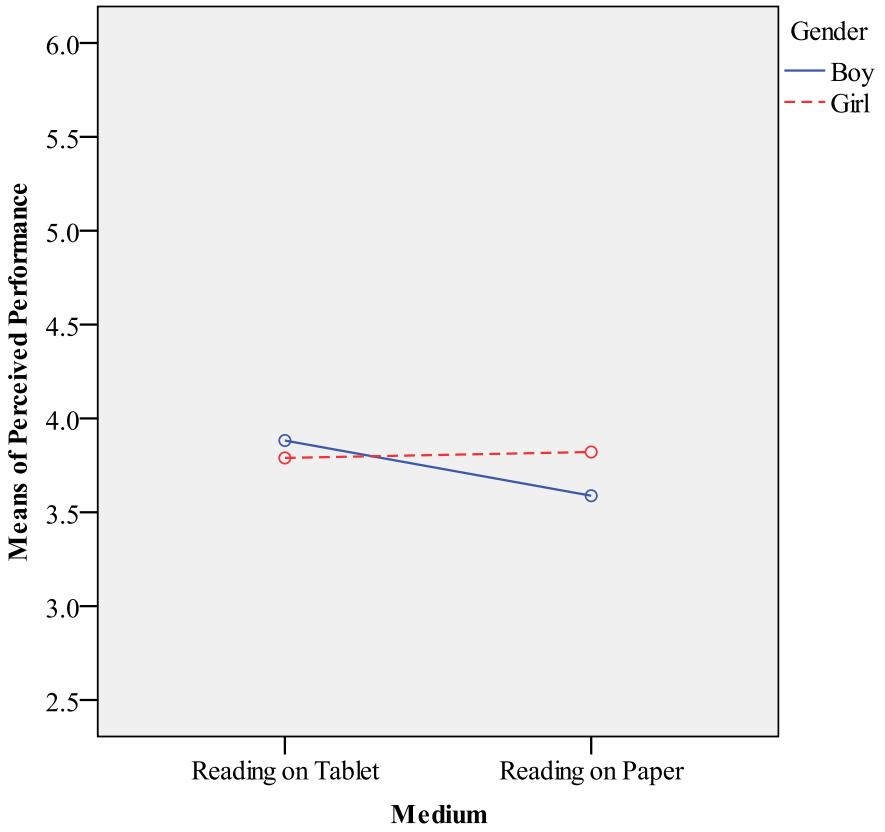

Figure 5. Means plot of Perceived Performance Score by Medium across Two Gender Groups for Grade 6 Students. Differences arising from medium were not considered statistically significant.

We have included Figure 6 (see page 11), which is the same type of informal bar chart we provided for Grade 4 results; readers should keep in mind, however, that differences arising from medium for Grade 6 students were not considered statistically significant.

Discussion

Young girls tend to be better academic performers than boys of the same age (Zembar & Blume, 2009). For a convenient summary, see http://www.education.com/reference/article/gender-academic-achievement/.

Part of the academic performance gap between boys and girls is attributable to the fact that it is harder for boys to become motivated and interested in academic tasks. In our study, grade 4 boys were more confident of their performance when using tablets, suggesting that the use of tablets may boost boys' levels of interest and motivation when asked to perform classroom tasks; we

tentatively propose that tablets may be of assistance in narrowing the average academic performance gap between young boys and girls.

On the other hand, the higher perceived performance noted for the boys may simply be due to the excitement associated with the introduction of a novel medium. It is also possible that our results may be due to boys' generally higher self-efficacy with technology (Broos, 2005). Further study is recommended.

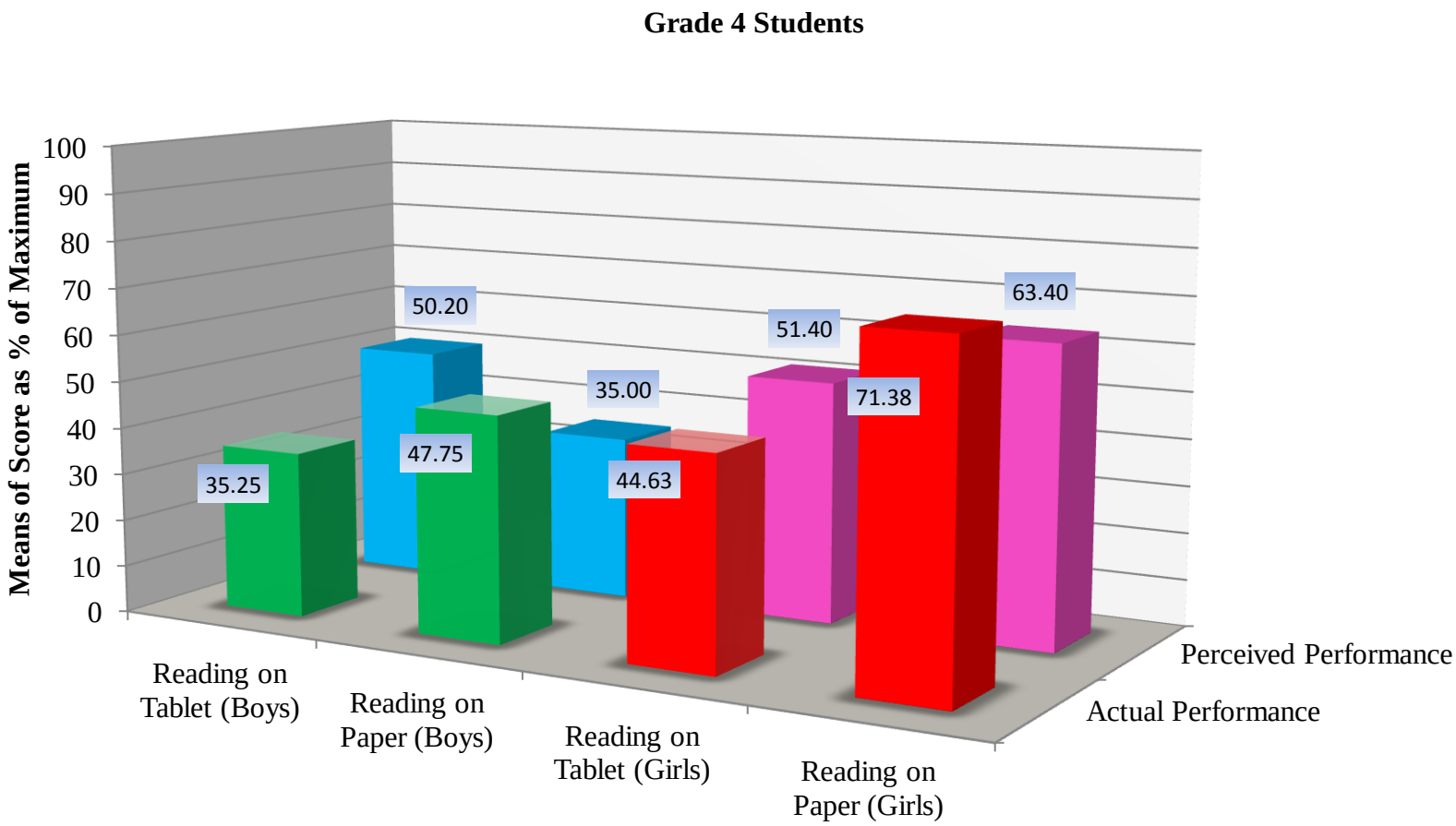

Figure 4. Grade Four Students' Means of Reading Comprehension Score and Perceived Performance, shown as percentages to provide a rough indication of the differences in actual and perceived performance.

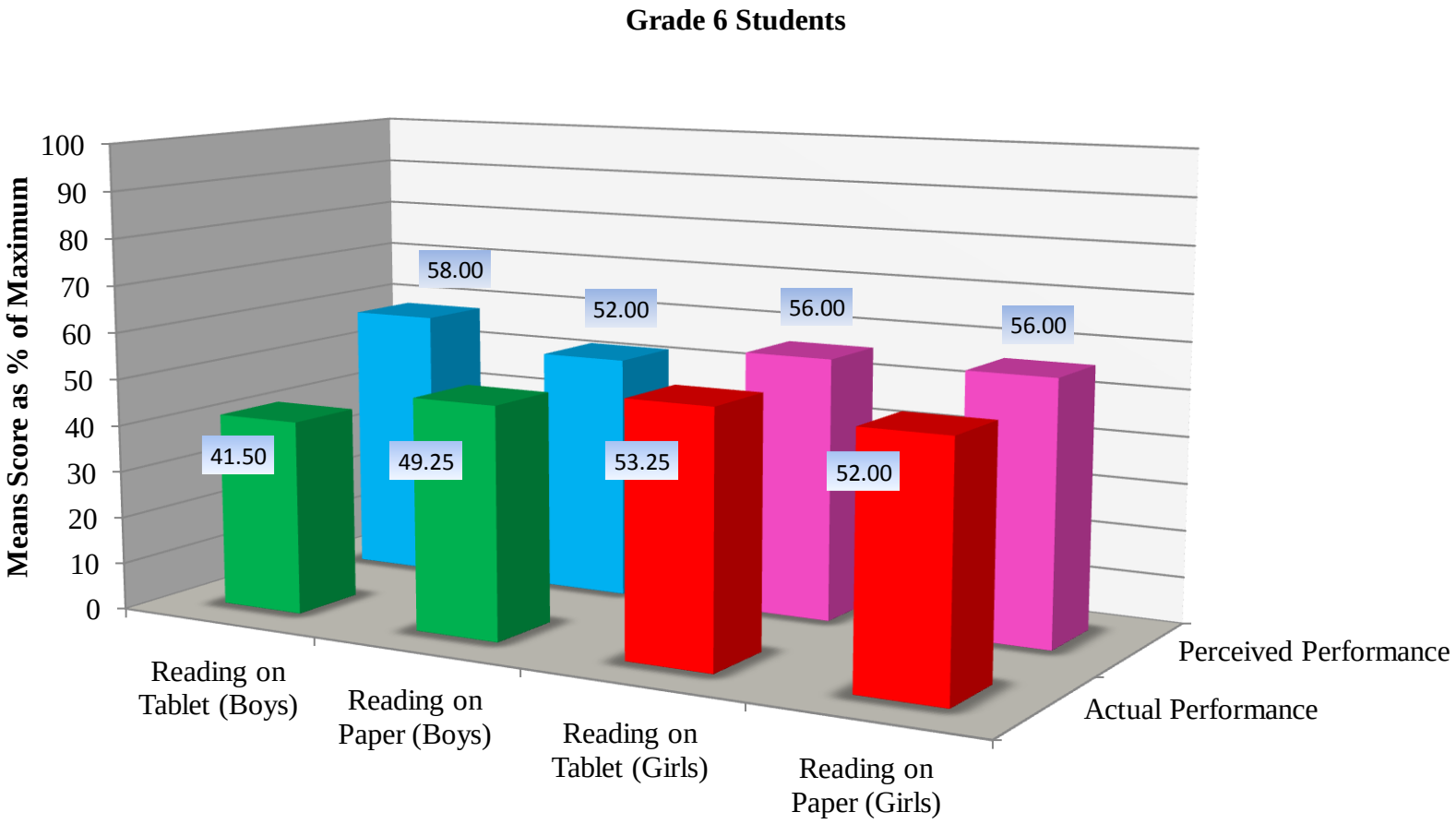

Figure 6. Grade Six Students' Means of Reading Comprehension Score and Perceived Performance, shown as percentages to provide a rough indication of the differences in actual and perceived performance. Differences arising from medium were not considered statistically significant.

Memory Retention (Grade 1)

We took two grade 1 classes and used one as the control group. Each group was asked to memorize 25 images in a three-minute period. The treatment group used tablets for the memorization task while the control group used printed paper. After three minutes, both groups were asked to perform some arithmetic exercises for one minute to prevent rehearsal of short-term memory. Then, subjects in both groups received printed sheets of paper containing 50 images, and were asked to select the 25 images they had attempted to memorize earlier. For each group there were 25 correct and 25 incorrect answers.

Memory Retention, Grade 1

The control group of 16 grade 1 students (aged 6-9, 9 males and 7 females) used printed paper and scored higher in the memory test than the tablet-using treatment group of 13 students (aged 7-9; 8 males and 5 females). The results are shown in Figures 7 and 8.

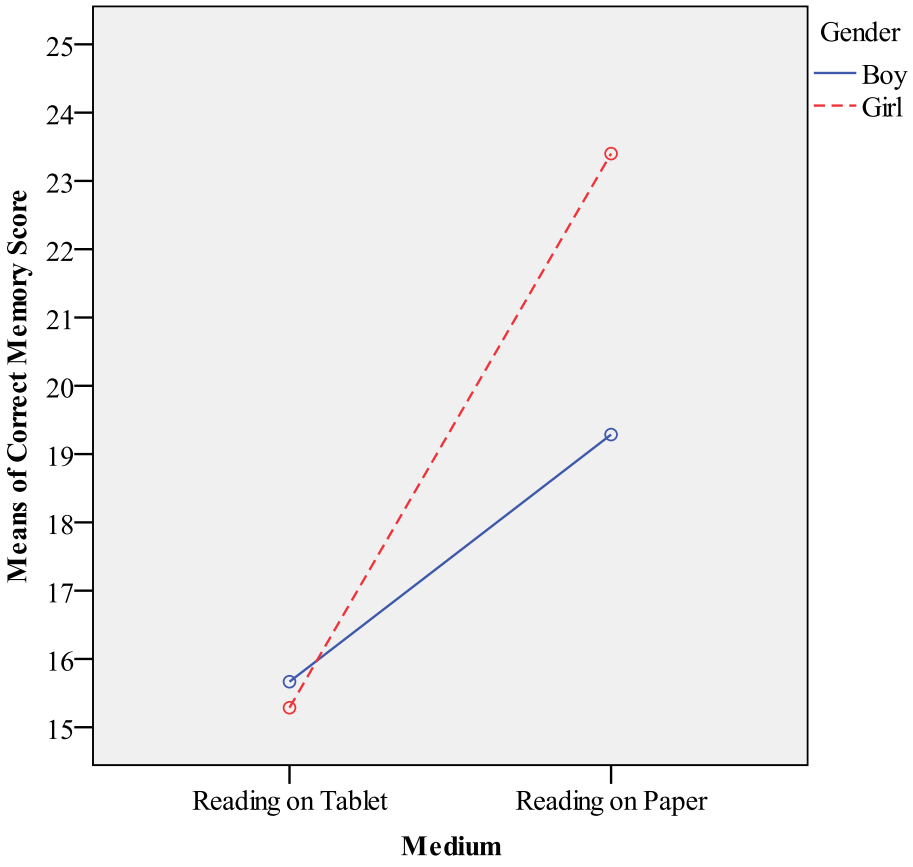

Figure 7. Means Plot of Correct Memory Score for Grade 1 Students.

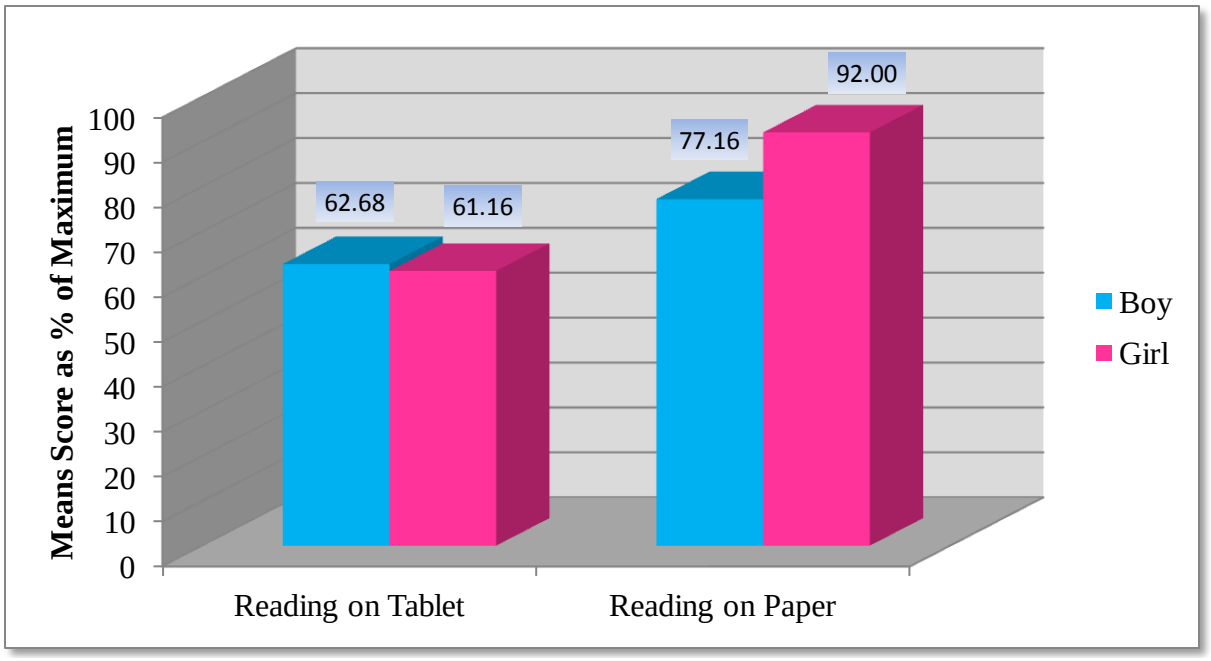

Figure 8. Means of Correct Memory Score for Grade 1 Students.

Discussion

Our results do not agree with previous research that found improvements in memory retention when subjects used tablet PCs (Ando & Ueno, 2010; Gasparini & Culén, 2012). We suspect a number of possible reasons for this discrepancy. Perhaps a 7-inch screen is not a sufficient size for use in the classroom, since many printed textbooks – a thoroughly established and proven technology – are substantially larger than a 7-inch diagonal.

It's important to note that when the conditions at memory encoding match the conditions at memory retrieval, memory retrieval is improved (Goldstein, 2011); we suspect that the poorer performance of our treatment group may be at least partially due to the discrepancy of medium between conditions at memory encoding and memory retrieval. The treatment group, who memorized images on a tablet, would have been at a disadvantage to the control group, since both groups selected their answers to the memory test using the medium of printed paper.

Based on these results we propose that tablets in education need to be used consistently both for learning (memory encoding) and for testing (memory retrieval). Future investigators could look more closely at this issue by utilizing one medium consistently (tablet or paper) for both memory encoding and retrieval, and comparing the results to students who use mixed media.

Academic performance (Grades 1, 4 & 6)

Tablets did not appear to affect students' grades in any significant manner for the period of the study. Teachers reported no meaningful changes in the academic performance of students who used tablets for one month. It is possible that the lack of an effect was due to the limited time of the experiment, and that over a longer period differences may become apparent.

It should be emphasized that the donated tablets were perceived by the children primarily as a platform for entertainment rather than a tool for learning**.** While this effect is not necessarily undesirable, sufficient time using a variety of relevant educational applications should be allowed to broaden young children's experience of touch-based devices.

A few months after the completion of this study, the newspaper Sing Tao reported that the Hong Kong Education Bureau in a review praised Chan's Creative School (HK Island) for its inclusion of technology in the classroom, asserting that such practices have helped to minimize the individual difference between students, developed students' potential, and encouraged them to use information technology for learning (Leung, 2012).

Part III: Thoughts

Investment in ICT education results in children who are familiar with, and develop a facility with, various technologies of ever-increasing relevance. Such investment can be worthwhile regardless of the exact magnitude of the benefits to academic success if it means that children will become better prepared to take advantage of ICT academically, economically, and socially throughout their lives. Other researchers have noted "the belief that such investments [in ICT for students] will pay off in the future because the use of technology will lead to educational attainment, and this will lead to employment, earning power and economic activity" (Plowman, Stevenson, McPake, Stephen, & Adey, 2011).

Given the increasing role of social networking services across almost all societies, it is crucial to recognize that the value of ICT for children must not be a purely academic consideration but also a social one: the ability and the skills to safely and effectively utilize a broad range of devices, software and services in a rapidly evolving and highly diverse technological landscape are increasingly important to all persons except very young children, to whom screen-based ICT may in fact be harmful (American Academy of Pediatrics, 2001; House, 2012; Ravichandran & de Bravo, 2010).

As noted by other researchers, "In this modern society of rapidly developing technology, children's ability to use ICT is increasingly vital to their success, both in education and in their life afterwards. The necessity of competence in this area is increasingly being recognized." (Vryzas & Tsitouridou, 2002)

While it is possible that ICT use in the classroom may include some undesirable effects, educators must weigh eventual disadvantages against the range of benefits conferred. ICT education is becoming more essential with every advance in the field of high technology. Scholars have been pointing out for more than a decade that "ultimately, the use of ICT will enhance learning experiences for children, helping them to think and communicate creatively, and work collaboratively. It will also prepare our children for successful lives and careers in an increasingly technological world." (Wheeler, 2001)

In spite of improving technology and rapidly dropping costs, the digital divide – which can be addressed relatively easily at the elementary school level – remains a serious global concern. We fear that rapid advances in ICTs for education will not include children from poorer areas or disadvantaged backgrounds, eventually leading to increases in the digital divide. It is our hope that ongoing developments in low-cost touch-based computing offer some solutions to the problem.

Future opportunities

Higher sample sizes lead to better statistical validity. We began this project with 49 tablets and sample sizes ranging from 13 to 36 subjects, and are looking to increase those numbers for future research and donation opportunities. If you would like to be involved, or if you want to provide feedback on this initiative, please write us feedback@thinkblaze.com.

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Appendix: The Data

Table 1

Means, Standard Deviations, and Analysis of Variance (ANOVA) Results for Comprehension Scores and Perceived Performance as a Function of Gender and Medium for Grade 4 Students

	Gender				ANOVA $F(1, 16)$		
	Boys (n = 11)		Girls (n = 7)		Between subjects	Within subjects	
Medium	*M*	*SD*	*M*	*SD*	Gender (G)	Medium (Me)	G x Me
Comprehension Scores[a]					3.59	19.40**	2.57
Reading on tablet	2.82	1.40	3.57	2.23			
Reading on paper	3.82	1.25	5.71	1.80			
Perceived Performance[b]					2.75	0.11	7.51*
Reading on tablet	3.51	1.11	3.57	0.99			
Reading on paper	2.75	1.15	4.17	0.88			

Notes. [a]Comprehension scores ranged from 0 to 8, higher score indicates better comprehension result. [b]Perceived performance ranged from 1 to 6, higher score indicates better perceived performance.
*$p < .05$. **$p < .001$.

Table 2

Means, Standard Deviations, and Analysis of Variance (ANOVA) Results for Comprehension Scores and Perceived Performance as a Function of Gender and Medium for Grade 6 Students

	Gender				ANOVA $F(1, 34)$		
	Boys (n = 17)		Girls (n = 19)		Between subjects	Within subjects	
Medium	*M*	*SD*	*M*	*SD*	Gender (G)	Medium (Me)	G x Me
Comprehension Scores[a]					1.29	0.88	1.75
Reading on tablet	3.32	1.89	4.26	1.50			
Reading on paper	3.94	1.75	4.16	1.77			
Perceived Performance[b]					0.09	1.01	1.55
Reading on tablet	3.88	0.65	3.79	0.73			
Reading on paper	3.59	1.17	3.82	0.59			

Note. [a]Comprehension scores ranged from 0 to 8, higher score indicates better comprehension result. [b]Perceived performance ranged from 1 to 6, higher score indicates better perceived performance.

Table 3

Means, Standard Deviations, Sample Sizes, and Analysis of Variance (ANOVA) Results for Correct Memory Scores and False Memory Scores as a Function of Medium and Gender

	Gender (G)						
	Boys		Girls		ANOVA $F(1, 24)$		
Medium (Me)	*M* (*SD*)	*n*	*M* (*SD*)	*n*	Me	G	Me x G
Correct Memory Scores[a]					15.55**	1.57	2.28
Reading on tablet	15.67 (3.74)	9	15.29 (3.07)	7			
Reading on paper	19.29 (5.50)	7	23.40 (1.14)	5			
False Memory Scores[b]					1.63	1.92	0.02
Reading on tablet	3.78 (4.90)	9	1.71(3.68)	7			
Reading on paper	1.86 (1.67)	7	0.20 (0.45)	5			

Note. [a]Correct memory scores ranged from 0 to 25, higher score indicates more pictures were correctly recognized. [b]False memory scores ranged from 0 to 25, higher score indicates more pictures were falsely recognized.
**$p < .001$